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PERSONAL VIEW

# Is there a superior simulator for human anatomy education? How virtual dissection can overcome the anatomic and pedagogic limitations of cadaveric dissection

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**ABSTRACT**
Educators must select the best tools to teach anatomy to future physicians and traditionally, cadavers have always been considered the "gold standard" simulator for living anatomy. However, new advances in technology and radiology have created new teaching tools, such as virtual dissection, which provide students with new learning opportunities. Virtual dissection is a novel way of studying human anatomy through patient computed tomography (CT) scans. Through touchscreen technology, students can work together in groups to "virtually dissect" the CT scans to better understand complex anatomic relationships. This article presents the anatomic and pedagogic limitations of cadaveric dissection and explains what virtual dissection is and how this new technology may be used to overcome these limitations.

Educators must select the best tools to teach anatomy to future physicians and traditionally, cadavers have always been considered the "gold standard" simulator for living anatomy. However, with recent advances in medical education and technology, we believe that the cadaver might no longer be the primary simulator for medical students. This article will present the anatomic and pedagogic limitations of cadaveric dissection and explain what virtual dissection is and how this new technology may be used to overcome these limitations. Virtual dissection is the act of manipulating computed tomography (CT) scan data in three-dimensions to reveal the different organ systems and discover anatomic relationships.

The major drawback of cadaveric dissection is that it is a representation of postmortem anatomy. In this environment, emptied veins and arteries appear very similar and airspaces such as the airways, lungs and bowel gas can never be truly examined. Arguably, the airspaces are an *essential concept* as all physicians must be very comfortable with evaluating these areas clinically – whether on X-ray or the physical exam. Practically, cadavers are cumbersome and difficult to reposition, constraining students' visualization of certain structures. Often, students must learn about these hard to access anatomic relationships through other resources, such as textbooks or online platforms, which are less efficient for learning because students have to consult multiple resources.

From a pedagogical perspective, curricula based on cadaveric dissection do not easily facilitate vertical integration or flexible curricula, which are key components of modern medical education. Vertical integration is limited since disease in cadavers is random, making it impossible for educators to properly develop a clinically oriented curriculum. While it may be possible to highlight some normal clinical applications (i.e. surface anatomy), this can also be accomplished through other modalities such as ultrasound. Furthermore, with cadavers, the dissection sequence is relatively fixed, which further limits the ability of cadaveric dissection to integrate effectively into case-based curricula. For example, traditionally the kidneys are not studied without first dissecting the anterior abdomen. Additionally, cadaveric curricula are less flexible and more difficult to personalize as students are unable to correct dissection mistakes or re-visit completed dissections.

Virtual dissection, or digital dissection, is an emerging area of interest for medical educators, radiologists, and anatomists. We believe that it can solve many of the anatomic and pedagogical barriers to learning encountered with cadaveric dissection. Currently, virtual dissection is performed on an anatomy visualization table (AVT), which is very similar to hospital radiology workstations, where students can work together to dissect the patient (Linköping, Sweden; http://www.sectra.com/medical/sectra_table). Patient CT scans are loaded onto a near life-size computer screen and through powerful software interactions students can manipulate the data to perform their dissection. For example, students can isolate a specific costovertebral joint and view it from all angles.

Many of the anatomic shortcomings of cadaveric dissection are solved by virtual dissection. Since, CT scans are typically performed on living patients, students can study how organs appear in real life. They can examine the normal volume of air in the lungs and intestines and understand how the epiglottis lies in an aerated oropharynx. Beyond demonstrating living anatomy, virtual dissection can integrate physiologic concepts. For example, most CT scans are performed with intravenous iodinated contrast in the clinical setting, so students can see the differential

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perfusion of organs and vessels based on relative blood flow. In addition, this allows better appreciation of the vascular anatomy such as the major branches of the aorta. This allows virtual dissection provides learners with additional learning opportunities not available with cadaveric dissection. However, it is important to emphasize that virtual dissection *must be performed with real patient scans* to allow for this type of learning. Digitally displayed artist renderings of the human anatomy *do not constitute virtual dissection*.

Virtual dissection has a clear advantage over cadaveric dissection when it comes to pedagogical opportunities. Without depending on cadaver preparation students are free to access the curriculum as often as needed, truly supporting flexible learning. Also unlike cadaveric dissection, the same CT scan can be dissected repeatedly and the "cut planes" can be customized to the students' specific questions. Most importantly, since *any* CT scan can be loaded onto the AVT, educators can truly vertically integrate their anatomy curricula demonstrating pathology in real patients alongside the normal anatomy. For example, in our first-year medical undergraduate anatomy curriculum which includes both cadaveric and virtual dissection, students are shown a case of scoliosis on the AVT during the cadaveric spine laboratory to augment their learning. Through virtual dissection, students appreciate how an abnormality of the spine will affect the entire patient including pulmonary function and gait.

A potential criticism of virtual dissection is the loss of haptic feedback that accompanies cadaveric dissection. It is true that when interacting with a touchscreen, students are not able to appreciate the way tendons, muscle, and bone feel and respond to forces. However, the loss of the haptic feedback in pre-clinical training may not be critical as students will rotate through the operating room during their clinical training, where they will be able to experience the feel of living organs. Other critics have cited that cadavers offer learning opportunities beyond teaching anatomy, teaching students the value of the clinical encounter, and early concepts of professionalism (Escobar-Poni and Poni 2006). While true, it is important for institutions to examine how these objectives are covered in their undergraduate curricula, and to decide whether cadaveric dissection is the best or only opportunity for this content. Additional potential limitations of virtual dissection include that we do not yet know how the cognitive load for this new technology compares to cadaveric dissection or if there are any learning implications to the transient nature of the dissection.

Virtual dissection is an extension of the trend to include radiological concepts in undergraduate pre-clinical anatomy courses. Numerous institutions, including our own, have published on the advantages of introducing basic radiology principles to medical students during their anatomy teaching (Phillips et al. 2013). Virtual dissection builds on these principles, further exposing students to the anatomy and physiology they will need to know in the clinic. During their careers, most physicians will be looking at patient anatomy and physiology on radiological studies rather than cadavers. Based on our five-year experience with virtual dissection, we believe that it is essential to have a radiologist involved in developing a virtual dissection program. Radiologists not only have access to medical imaging, but also a deep understanding of how CT scans characterize human tissue and how disease affects the body. Just as anatomists are experts in cadaveric dissection, radiologists are experts in virtual dissection.

Although early in its implementation, we firmly believe that virtual dissection will not only revolutionize anatomy education, but also better prepare medical students for clinical practice. Students who experience virtual dissection will be better prepared clinically because they will have early exposure to both normal and abnormal radiology anatomy and begin to develop the image-interpretation skills that they will use throughout their careers. The anatomic and pedagogical advantages of virtual dissection provide students with the opportunity to study living anatomy and physiology and provide educators with additional opportunities to build intentional and vertically integrated curricula. Based on our early experiences, we trust that virtual dissection – with or without cadaveric dissection – will bring renewed student enthusiasm for anatomy as learners will clearly see its clinical relevance.

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The authors report no conflicts of interest. The authors alone are responsible for the content and writing of this article.

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